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ABSTRACT

The educational philosophy and programs for the education of manufacturing and production engineers in these three countries are discussed. Included are curriculum standards, course content, differences in prestige of the engineering profession, and the types of educational institutions offering engineering instruction. (MLH)

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MANUFACTURING ENGINEERING INSTRUCTION IN GREAT BRITAIN, SWEDEN AND GERMANY

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Introduction

The education of engineers for the manufacturing and production industries of Europe differ substantially from country to country. This is because the educational philosophy differs from country to country. For example, in Great Britain the first degree is normally taken after three years at the University while in Sweden this involves four years of study and in Germany five years. There is also a wide difference in the degree of standardization of the curriculum from country to country. In Great Britain the course content in a given area such as Manufacturing Technology differs substantially from University to University while in Germany the curriculum is highly standardized so that a student may move from one Institution to another with little change in overall course content.

In Great Britain engineering is taught both at Universities and Technical Colleges while in Sweden and Germany engineering is taught at Polytechnic Institutes and Technische Hochschulen (Institutes of Technology). There is also a basic difference in the relative prestige of students and faculty associated with manufacturing engineering in the different countries of Europe. In Germany those involved in manufacturing engineering enjoy far more prestige than in Great Britain and in general more intellectually capable students are attracted to engineering in Germany than in Great Britain. In Sweden the course of the future is not clear. While in the past engineering was regarded as a very desirable profession, it is presently losing ground to other fields and many of the most talented students are showing a preference for medicine and law rather than

engineering which they regard as dull, confining, and less financially rewarding.

Great Britain

In Great Britain (1) the decision to enter a university and to pursue a given course of study is usually made at an early age. Students destined to go to college take a different path following the sixth year of study and begin to specialize after 9 years of school (age 15). Before specializing, grammar school students must pass an "ordinary level" examination in subjects selected from a large list including languages, history, geography, mathematics, physics, chemistry, etc. Upon passing this examination students choose advanced subjects in direct preparation for their course of study at the university. Those entering engineering or science will prepare for advanced level examinations in mathematics, chemistry and physics. To offset the lack of balance in the advanced level many grammar schools sponsor a number of societies or clubs concerned with history, philosophy, politics, literature, chess, music, etc., where a pupil may delve into subjects of special interest under the guidance of a master. This activity is not required and only those electing to take advantage of it are broadened.

While this is the path normally taken, there is an alternate route. A student who has successfully taken courses leading to an Ordinary National Certificate in production technology (at age 18) may take a further three year course leading to a Higher National Certificate (at age 21), and then enter a three year undergraduate course of engineering study at a university.

A result of the system described above is that a British student begins his university training at a relatively high level of scientific training, making it possible to take the first degree (BSc) in three years. The training is rigorous and emphasizes basic knowledge rather than applications. Examinations must be passed at the end of each year of study and the third and final year involves a project.

Upon leaving the university a British student will normally enter a two year apprenticeship in industry. A student may however, elect to engage in one year of practical work in industry before going to the university in which case his postgraduate apprenticeship is reduced to one year. It is also possible to substitute one of the two years by further training in the university leading to a MSc degree. This involves a full 12 months of the study of advanced subjects and pursuing a study project of about three months duration.

The British PhD differs from that in the USA in that it does not require the passing of any examination. It is strictly a research degree which is examined by a thesis prepared after from 2 to 4 years of work. To qualify for the PhD a student must usually take a BSc degree at least at the 2.1 Honors level. (British BSc degrees are awarded with the following distinctions: First Class Honors, 2.1 Honors, 2.2 Honors, 3rd Class Honors, pass.) Most PhD students work as assistants.

An important characteristic of an engineering education in Great Britain is that professional qualification is granted only after a substantial period of practical industrial experience and the attainment of a position of responsibility. The title of "Chartered Engineer" (C. Eng.) is awarded qualified engineers by the major engineering societies.

Requirements for this distinction are: to have reached an age of 26 years, to have passed qualifying examinations in a field of specialization and to provide proof of two years of apprenticeship training and that a responsible position has been held for a certain period of time. Thus, a British engineer is qualified in a manner similar to that employed in the medical profession.

The British Chartered Engineer must have demonstrated not only the ability to tackle complex problems analytically, but also will have been exposed to the practical aspects of engineering and will have demonstrated a capacity for leadership.

Manufacturing engineering is taught at both Universities and Polytechnic Institutes in Great Britain as follows:

Universities	Polytechnics:
*Aston (Birmingham)	Brighton
Birmingham **	Dundee
Bradford	Glamorgan
Brunel	Lanchester
Cranfield	Leeds
Imperial College (London)**	Liverpool
Lancaster	Manchester
*Louchborough	Oxford
Manchester (UMIST)**	Sheffield
*Nottingham**	Trent
Salford**	
*Strathclyde (Glasgow)	

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* University having Production Engineering Departments as well as Mechanical Engineering Departments.

** Universities producing most of the PhD's in manufacturing engineering.

In most of the universities listed above Manufacturing Engineering is an option within Mechanical Engineering. For example, at The University

of Birmingham there are about 50 Mechanical Engineering graduates per year. Of these about 20 specialize in Engineering Science while about 30 take a more applied curriculum that includes some training in manufacturing engineering and the elements of management. There is also an Engineering Production Department at Birmingham that produces about 10 BSc's per year. These students follow a series of courses directed somewhat more toward management and organization than the corresponding stream in Mechanical Engineering. At Manchester (UMIST) between 30 and 45 BSc students are graduated each year who have taken the manufacturing engineering option in Mechanical Engineering.

The programs in the Universities and Polytechnic Institutes differ principally in that more research and post graduate instruction takes place in the universities and the instruction in the universities is somewhat more sophisticated.

It is estimated that a total of about 400 BSc students per year study manufacturing engineering in all of Great Britain.

Most of the specialization in manufacturing engineering in Great Britain takes place at the MSc level, but this involves relatively few students. For example, about 10 MSc students are produced per year at Birmingham and between 15 and 20 at UMIST.

The MSc degree course in Machine Tool Technology at The University of Birmingham is closely associated with the British machine tool industry, involving an industrial steering committee and many special lecturers from experts in industry. This one year course qualifies for a full year of the apprenticeship training required for the C. Eng. certification. The MSc course at UMIST is also similarly qualified and

is quite a bit like that at Birmingham. The cost to a company of having engineers from industry take the MSc degree as part of their apprenticeship is very low since government funds for this training are available from the Engineering Industry Training Board. However, despite this fact few companies take advantage of the opportunity and about half of the MSc degree students are from abroad and self financed.

An interesting feature of the MSc program at Birmingham is that it begins in January instead of September. This is to enable new BSc graduates to spend the first few months after leaving the University with their sponsoring companies.

The MSc programs at Manchester (UMIST) and Birmingham are quite practical as may be seen from reference to Figures 1 and 2.

In addition to BSc and MSc students between 5 and 7 manufacturing engineering PhD's are produced per year at both UMIST and Birmingham. The programs at each of these institutions also involve about 10 post doctoral fellows who spend full time on research.

At the present time there is concern in Great Britain due to the low output of qualified manufacturing engineers relative to the requirements of industry. A working party has been organized by the Science Research Council (equivalent to the NSF in the USA) to determine ways of improving the output of manufacturing engineers.

Figure 1

MSc Program in Manufacturing Technology in the University of Manchester (UMIST), Department of Mechanical Engineering

(Total time required is 12 to 15 months.)

		Total Lecture Hours
I	First Five Weeks of Term - Introductory Lectures	
	1. Machine Tools and Manufacturing Processes	25
	2. Engineering Materials	10
	3. The Control of Production	10
	4. Computer Programming	10
	5. Machine Dynamics	10
	6. Plasticity	10
	Total Hours	75
II	Remainder of Term 1 and Term 2 (15 weeks)	
	Four of the following seven groups of lectures must be attended.	
	Group 1: Machine tool structures, elements, vibrations	45
	Group 2: Machine tool drives, numerical control systems	45
	Group 3: Production control, work measurements, personnel management	45
	Group 4: Performance of machine tools, use of N.C. machines and manufacturing metrology	45
	Group 5: Metal cutting, mechanics and machinability	45
	Group 6: Electrical, chemical and physical machining processes, metal forming technology	45
	Group 7: Welding and bonding, casting and powder metallurgy, polymer engineering	45

[Groups I and VI and II and VII are mutually exclusive.]

Design oriented students will normally take I, II, III and IV or I, II, IV and V.

Manufacturing oriented students will normally take III, IV, V, VI or IV, V, VI, VII or III, V, VI, VII or III, IV, V, VII.

III Terms 3 and 4 - project work and preparation of Dissertation.

In addition, there is experimental work and demonstrations.

Figure 2

MSc Program in Machine Tool Technology
at The University of Birmingham

I Manufacturing Processes and Machine Tools (53 hrs): the cutting process, machine tool kinematics, metallurgical considerations, new manufacturing techniques.

II Properties of Materials (46 hrs): general materials behavior, steels, cemented carbides, ceramics, design considerations, casting, welding, wear.

III Industrial Economics (57 hrs): general principles of accounting, capital expenditure evaluation, economics of manufacturing processes.

IV Manufacturing Systems (45 hrs): principles of systems engineering with applications to manufacturing systems.

V Static and Dynamic Characteristics of Machine Tools and Metrology (55 hrs): metrology, machine tool accuracy, thermal effects, alignment, principles of dynamics, stability of motion, vibration of structures, machine tool chatter, noise in machine tools.

VI Automatic Control (45 hrs): electric, hydraulic, and numerically controlled systems.

VII Design of Machine Tool Elements (60 hrs): spindles, drives, bearings, lubrication, cams, bolted joints, computer aided design.

VIII Instrumentation (13 hrs): transducers, amplifiers, recorders, applications.

IX Planning and Control of Production (60 hrs).

X Industrial Relations and Labor Economics (45 hrs).

In addition to these lectures there are experiments and demonstrations, a seminar, industrial visits and a project assignment.

Sweden

In Sweden Manufacturing Engineering is handled as an option of the Mechanical Engineering Course which takes a minimum of 4 years and requires a thesis. The degree awarded is Civilingenjör which in the past has been considered to be equivalent to the MSc degree in the USA. Students are prepared for study at the University in much the same manner as in England, the last three years in high school being devoted to the intensive study of mathematics, physics and chemistry. Pre-university training begins at age 7 and normally takes 12 years.

Manufacturing Engineering is now[1] taught at the following institutions in Sweden:

1. Royal University of Technology-Stockholm (KTH) (235)
2. Chalmers University of Technology-Gothenberg (CTH) (192)
3. University of Lund (125)
4. University of Linköping (170)
5. University of Luleå (150)

The total number of mechanical engineers now entering each year are given in parenthesis. A certain percentage of these students will take the special course "Production and Management" and a smaller number will take

[1]Until about 1964 engineers were educated in Sweden at the first two institutions. Since that time engineering education has increased from about 150 graduates per year to 900 (a six fold increase!). This has been made possible by addition of engineering instruction to the programs at Lund, Linkoping and Luleå in the far north. This is a result of the government deciding that all students have an equal opportunity of studying engineering. The result has been a drastic decrease in quality which concerns the faculty (2).

higher courses in Manufacturing Technology. For example, at Chalmers, of the 192 M. E. students only about 25 will take the Manufacturing Engineering option, and about 15 students will take a post graduate program. Interest in post graduate studies has been falling in Sweden during the past few years as it has been in the USA.

All of the above mentioned Universities (except Lund) are polytechnic institutes concerned only with Engineering and Applied Science as are the Technische Hochschulen in Germany. The 3500 undergraduate and 500 graduate students at Chalmers are distributed between the following six schools:

1. Engineering Physics
2. Mechanical Engineering
3. Electrical Engineering
4. Civil Engineering
5. Chemical Engineering
6. Architecture.

The entire field of Mechanical Engineering at Chalmers is divided into the following three areas of concentration:

1. Design, Heat Transfer and Power Engineering
2. Production and Management Engineering
3. Naval Architecture.

The curriculum for the first year and a half is common to all mechanical engineers and all mechanicals take the first course in Production Engineering. Only those electing the Production and Management option take further courses in Manufacturing Engineering during the third and fourth years of study.

A recent decision of the Swedish Parliament now requires all engineering programs to spend a minimum of 4% of the available time on subjects concerned with environmental and working conditions.

At KTH the first two years of the mechanical engineering program are devoted to the study of basic studies including: drafting, thermodynamics, materials, machine elements and electrical technology (all taught by the mechanical engineering faculty), together with advanced mathematics, statics, dynamics and strength of materials (taught by other faculty). During the last two years, mechanical engineering students specialize in one of the following fourteen areas:

Refrigeration
Manufacturing Engineering
Wood technology
Industrial Economy and Organization
Machine Tool Design
Machine Design
Machine Elements
Welding
Ship Building
Paper technology
Power technology
Reactor technology
Hydraulics and Pneumatics
Heating and Ventilation

About 20 students are admitted to each field of specialization. In addition to special courses in the field of specialization a few subjects such as the following may be elected during the third and fourth years:

Computer languages
Computer applications
Control Engineering
Optimization and System Theory
History of Technology
National Economy
Law for Engineers
Industrial Psychology
Ecology

The last three months is devoted to a thesis study and about 50% of the students do this in industry.

Eighty five days of practical workshop experience in industry is required for graduation (this was formerly 6 months before the recent increase in the number of engineers being trained).

The doctor's degree in Manufacturing Engineering at KTH takes from 4 to 5 years, about 25% of the time being devoted to advanced courses and seminars. The remaining 75% is concerned with an original research study.

In Sweden, which has a population of about 8 million people, less than 900 Civilingenjören are graduated each year and of these only about 15% will have specialized in manufacturing engineering. However, there are many other schools that turn out a more practically oriented product leading to the somewhat less demanding degree of Ingenjor. This degree requires 4 years at a special technical high school instead of the 3 years of academic high school plus 4 years at the Technical University required for the Civilingenjör degree.

Germany

In West Germany manufacturing engineering is taught in the following technische hochschulen:

1. Aachen
2. Berlin
3. Bochum
4. Braunschweig
5. Darmstadt
6. Dortmund
7. Hannover
8. Karlsruhe
9. München
10. Stuttgart

The basic course material available at each of these institutions is highly standardized both with regard to course content and quality of instruction. The major difference lies in the character of the Research Institutes. In the field of manufacturing engineering, there will normally be one academic chair per university (although there may be as many as three at some of the larger universities such as Aachen). The Professor holding such a chair will normally also be the director of a Research Institute which strongly reflects his area of interest and expertise. The Institute Director is often also editor (Herausgaber) of a technical journal that publishes technical papers in his field of expertise. For example, the institutes at Braunschweig, Aachen and Munich are the most important seats of research on grinding while Hannover and more recently Stuttgart are famous for forming research. However, when the head of an institute changes, the field of emphasis is apt to shift rather dramatically.

The institutes are frequently large research establishments which conduct highly practical studies that would normally be done in industry in the USA. For example, the institute at Aachen (WZL = Laboratorium für Werkzeugmaschinen Und Betriebslehre) which is shared by three Professors involves about 300 students specializing in manufacturing engineering each of which will do a master's thesis (diplomarbeit), about 120 research workers holding the Diplom. Ing. degree, and a few postdoctoral workers. The forming institute at Stuttgart (Institut für Umformtechnik) consists of three postdoctoral workers, 25 Diplom. Ing. and a large number of students involved in research projects required for the first degree.

Students coming to the Technical University are carefully screened, have a strong background in mathematics and are quite mature. A high level series of examinations (arbitur) must be passed before a German student is eligible to enter the university. Also, the Technical Universities require a minimum of 26 weeks of full time shop experience of entering students.

There are other specialized polytechnic institutes in Germany that produce graduates with a more practically oriented outlook. These programs take less time and lead to the degree Ing. instead of Diplom. Ing. It is possible for a good student to transfer from one of the more practically oriented polytechnics to a Technische Hochschule and a number of students do this each year.

At the present time there is talk of streamlining the instruction in the Technische Hochschulen so that the degree Diplom. Ing. may be obtained in four years. Details of such a program are presented in reference 3.

The doctor's degree in manufacturing engineering (Dr. Ing.) does not require any course work beyond the first degree but is purely a research degree in Germany as it is in Great Britain.

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